THE KNOWLEDGE SEEKERS

Creating Centers for the Performing Sciences

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*A COMMUNITY'S ABILITY TO CREATE TECHNOLOGY ,
TURN IT INTO A PRODUCT, AND GET VALUE FROM IT
WILL BE THE STANDARD THAT DETERMINES
ITS SUCCESS IN THE 21ST CENTURY*

W. Arthur Porter, Ph.D.

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No state funds were used in the preparation of this book.

I dedicate this book to my father
who taught me the value of
learning, anticipating, initiating and
adapting—and to always do them with integrity.

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THE DIFFERENCE BETWEEN CREATING JOBS AND CREATING WEALTH IS KNOWLEDGE. WE MUST UNDERSTAND THAT KNOWLEDGE IS THE NEW COIN OF THE REALM. TO GAIN A COMPETITIVE ADVANTAGE IN A CHANGING GLOBAL ECONOMY, WE MUST LEARN HOW TO LEVERAGE EACH COMMUNITY'S INTELLECTUAL RESOURCES.

W. Arthur Porter

Foreword

Not long ago, the Houston Advanced Research Center hosted a forum featuring four pioneers of science, Aaron Cohen, Michael DeBakey, Jack Kilby and Al Trivelpiece. Each shared concern about the declining investment in U.S. research and his hopes for future technological advances. I was particularly struck when Aaron Cohen commented that the greatest advancements in human history have resulted from "those few foresighted individuals who envisioned a better future and sought to make it happen."

The world has not always been smart about husbanding its natural resources or improving the human condition. HARC was created to help society become smarter about these challenges and apply the intelligence we've been given. It stands as an example of what can happen when bright minds from industry, government, and academia work together to solve problems we hold in common.

Besides their social value, R&D centers such as HARC can bring economic value and vitality to their community, better jobs, better educational systems, and a better quality of life for all. In these pages, Skip Porter shares his unique perspective of the critical role that collaboration among university, industry, and government partners can play in a community's future—how "centers for the performing sciences" can take new ideas, turn them into a product and return value to our communities.

George P. Mitchell
Chairman and Chief Executive Officer
Mitchell Energy & Development Corp.

Acknowledgments

I now know how hard it is to finish a project like this and why it feels so good to thank those who helped complete it. I thank first the two Georges—George Mitchell for the courage to start HARC and for encouraging me to write about it, and George Kozmetsky for the years of collaboration on many related projects and the generous grant to see it published and distributed. Both are on HARC's board and have provided me with many stimulating discussions. I am fortunate as well to have them as friends.

I thank Advantest Corp. for supporting my chair at HARC during the period this book was written as well as my colleagues at HARC and other HARC collaborative institutions, many of whom are referred to in these pages, for the learning experiences. I hope that my references to a number of those experiences provide the reader with at least some of the insight they provided me.

Finally, I thank Barbara Peyton and Gregor Rae whose steady support, probing minds, and get-it-done attitude kept the project from being yet another draft on my desk.

W. Arthur Porter

I would be pleased to have the readers' thoughts and to begin a dialogue about the topics touched upon in this book. Please visit *The Knowledge Seekers* at the HARC web site <http://www.harc.edu>.

Introduction

We live in an age of unprecedented—and at times, unsettling—change. To most of us, it seems as though life is stuck on “fast forward” or, in Woody Allen’s phrase, that the world has “too many moving parts.”

As disturbing as change may be, it can also mean enormous opportunity. This is especially true when change is driven by technological discoveries and innovation, as in our own day. The real challenge is equipping our social, political, and economic institutions to keep up with advances in science and engineering.

According to Skip Porter, the solution lies in an entirely new kind of organization—a collaboration of corporations, universities, and governments—that will enable modern society to “bridge the gap” between pure research and the marketplace. In this book, he lays out a rationale and blueprint for what he calls “the missing piece” in our efforts to do business in a changing world.

Dr. Porter’s prescription for our time is shaped by his 30 years of first-hand experience managing high technology research and applications. His ideas should be carefully considered by any community wanting to take advantage of the tremendous opportunities that are before us in the 21st century.

Norman R. Augustine
Chairman, Lockheed Martin Corporation

Chapter 1
The New Coin of the Realm

> THE KNOWLEDGE SOCIETY WILL INEVITABLY BECOME FAR MORE COMPETITIVE THAN ANY SOCIETY WE HAVE YET KNOWN—FOR THE SIMPLE REASON THAT WITH KNOWLEDGE BEING UNIVERSALLY ACCESSIBLE, THERE WILL BE NO EXCUSES FOR NON-PERFORMANCE. THERE WILL BE NO "POOR" COUNTRIES. THERE WILL ONLY BE IGNORANT COUNTRIES.
>
> *Peter F. Drucker, author and educator*

Never in the history of the world has the product of greatest value been so easy to move. When we were shipping silks and spices, timber and ivory across oceans, it was the great port cities where commerce grew. These cities were celebrated for their richness and grandeur and lured many a voyager to their shores hoping to amass the means for personal wealth. Indeed, one of President Thomas Jefferson's reasons for funding the Lewis & Clark Expedition was to find a waterway to the Pacific so this nation could compete for Asia's trade.

Today, any community can be a port city because the product of greatest value is what comes from the human mind—our intellect.

Knowledge is the new "coin of the realm" and transmission of that most valuable commodity now moves instantaneously. You do not need to load the formula for the cure to AIDS on an airplane or a ship to move it. You simply move "intellectual products and properties" across the Internet or fax line.

As each day passes, I see a growing global realization that intellectual property is the product of the next millennium. Any region or country intending to compete in the new market must be prepared to set up the trading routes needed to sustain success, to ensure a steady stream of "raw" material, and to create value-added products. A community's ability to create technology, to turn it into a product, and gain value from it will be the standard that determines its success in the 21st century.

For many communities this involves putting in place the "missing piece"—the infrastructure or "port" where intellectual property can be shipped commercially. I call this missing piece the Center for the Performing Sciences. In these pages I've tried to capture the lessons I've learned through the creation and development of the Houston Advanced Research Center (HARC), our

“Center for the Performing Sciences” in Texas. These observations include how similar institutions have fared, the university’s role in the new economy, and the impact of a changing federal laboratory mission, particularly as it relates to the United States. Also, I will explore some of the changes that even our largest industries are undergoing with respect to research and development and how they can benefit from a Center for the Performing Sciences.

While explaining how Centers for the Performing Sciences provide the missing link between the research laboratory and the marketplace, I will also discuss the many issues surrounding their creation.

Leaders from all over the world visit HARC on a regular basis. They want to know why, what, and how. In today’s fast moving world, they seek a formula for creating a center such as HARC. There is no single formula that will work universally. One size does not fit all!

Creating a Center for the Performing Sciences requires enormous commitment, investment, patience, and certainly luck. The location, resources and culture of the community all play a significant role and what succeeds in one place may fail miserably in another. Don’t expect a “plug and play” formula. This is as much about personal chemistry and emotional commitment as it is about vision and strategy. It also demands a rare breed of individual—what I call the “two percenters”—about whom I will talk later.

My hope is that this book will offer practical guidance to inspired business, political, academic, and community leaders and a better understanding of the underlying cultural and market issues that must be understood in order to create such a center. This book is not about science, because scientists are seldom the driving force behind the initial creation of such centers. Instead, these pages contain the thoughts and lessons that I would like to share with those seeking to understand the HARC model.

While the issues I’ve faced in Texas may not necessarily apply in all cases, I believe the lessons will be helpful. Most of all, I hope readers will be inspired to support the creation of science based business in their own communities and that, by creating the missing link, their citizens will benefit from their own Center for the Performing Sciences.

Chapter 2
A New Design

In 1970, two years after taking a leave from the semiconductor R&D labs at Texas Instruments (TI), I completed my doctoral degree at Texas A&M University and was working there as an assistant professor of electrical engineering while helping the university develop the Institute for Solid State Electronics. This period for the United States was a heady time of growth in R&D and generally there was strong government support for research and development. It was also a down period for the micro-electronics industry, and TI was focusing on new automated processes for manufacturing integrated circuits, an area in which it had invested heavily.

My return to the R&D labs offered significant opportunities for me because of the investments TI had made in programs I had developed there earlier. I had also just received the first government R&D contract for the electrical engineering department at Texas A&M. So, I was faced with the interesting dilemma of either returning to TI or remaining at Texas A&M as a professor—continuing with the development of the Institute for Solid State Electronics and consulting for TI. Because of my interest in finding ways for the academic and industrial sectors to work together and my belief that this is more effectively done in the academic setting, I decided to extend my leave and remain at Texas A&M.

Looking back, I believe this was a fortuitous decision, because it facilitated the learning process of what the real challenges are in bringing an academic institution and a micro-electronics company together, even when good personal relationships are already in place.

For Texas A&M, which wanted a world-class research center in the emerging micro-electronics field, there was a need for a strong faculty, knowledgeable and committed to the semiconductor and micro-electronics world. For Texas Instruments during a depressed economic period, it was convenient to maintain a working relationship with individuals the company could not justify employing on a full-time basis.

This was during the early days of the space program, and I had received a contract from the Marshall Space Flight Center to explore the possible advantages of processing semiconductor devices in space for use on earth. This was driven by the opportunity to exploit novel thermal and vacuum conditions existing in space. So, I was able to continue working with industry to engage and support the government sector through the space program, pursue my own curiosity driven research, and do all of that in the academic environment of Texas A&M University.

All of this proceeded rather well over the next five years. The capabilities of our Institute for Solid State Electronics continued to improve. This led to the next opportunity for strong industry, academic, and government collaboration which occurred because of what we all remember as the “energy crisis.”

Americans were enduring long lines at gas stations, and prices of $100 a barrel for oil were predicted not only by the oil companies but by the banks as well—but that’s another story. Consequently, I wasn’t surprised when I got a call one day from Jack Kilby, , the director of the semiconductor R&D lab when I left Texas Instruments and, as all the world knows, the inventor of the integrated circuit and the hand-held calculator.

Jack Kilby needs no introduction, but I can share some personal insight. One of the larger members of our society, Jack stands some 6 feet 8 inches. He is a quiet, unassuming Kansas farm boy who is a great photographer, family man, and grandfather, is exceptionally well read, and is keenly interested in a number of topics.

He’s also a man of action. Jack and I found resonance in our complementary styles of approaching a problem. As we began to develop what we hoped would be a new way to harness solar energy as an economical alternative for providing the electrical needs of the average household, we started a university, industry, and government collaboration. Jack is now one of my closest friends in life, a friendship which developed through the years we worked together in the labs at Texas A&M developing a spherical solar cell system which would have been a competitive energy source for residential use.

Our project was based upon finding a better idea for capturing the sun’s energy to produce electricity, which is what a photovoltaic device, or solar cell, does. Of course, mankind had known how to do that for some time, but the trick was improving the efficiency and finding a reasonable way to store it. Jack believed he had better ideas, and we invited another former TI colleague, Jay Lathrop, to join us in creating this new technology. We did this work in my labs at A&M’s Institute for Solid State Electronics. Jack used funding from TI, which had the right of first refusal for licensing under its agreement with Jack.

Now, most solar cells are flat like a plate and when the sun hits the silicon from which the cell is built, the light energy causes a ‘free’ electron to be generated. That electron has to travel across a junction, much like a soldier behind enemy lines trying to break through to his allies. This “no-man’s” region is called the “forbidden zone,” and if the electron manages to successfully cross it, then it can be put to work toasting bread, brewing coffee, or powering a computer.

The breakthrough idea that Kilby, Lathrop and I worked on 20 years ago—and that later formed the basis for several patents—was to create a spherical solar cell. Instead of altering an existing flat cell, we recognized that it was necessary to create a mechanism that improves the probability that an electron will make it across the forbidden zone.

The conclusion that we reached about improving a photovoltaic device is similar to one I've now reached about improving technology transfer. There is a gap to be transcended. Modifying existing structures is no substitute.

We need a new approach to collaboration that nurtures and rewards the process of bringing together talent and technology from university, industry, and government. This design would not be limited to the technical side of managing talent and technology but would also address marketing, management, and financial issues.

Universities have not operated under this model, and it is debatable whether they should. This is especially true for state universities constrained by the politics of spending the public's money as well as with trudging through layers of bureaucracy.

A new design is needed because the world is changing. Society has progressed from an agrarian-based economy, to an industrial revolution, to a knowledge-based economy where there is the individual and intellect. Those companies that know how to use that intellect will succeed. The days of having one job in life, retiring, and getting the gold watch are long gone. Today and in the future individuals will change jobs frequently and will constantly need to update and upgrade skills. The manner in which the knowledge-based economy operates—where the Internet is the vehicle and the Center for the Performing Sciences can make any city a port—is changing the way we think, compete, and work.

We appear to be moving in an economic direction where there are no longer jobs, just work. Many different companies across multiple industries have similar, if not exact, knowledge needs and this "coin of the realm" is circulated in a very different manner.

All of this points again to the missing piece—where top talent and technology that can serve multiple needs can come together and solve problems in a collaborative way. What is needed is a place to spin-off new companies based upon new technologies, to help create new products for existing companies, and to stimulate interest in the value of knowledge as well as its creation within the community.

Centers for the Performing Sciences can work with industry to provide both talent and technology, with government to support economic development, with universities to further train and provide experience in the use of technology for their faculty and students, and with the community to raise the level of awareness of the importance of technology in a knowledge-based economy.

Chapter 3
Crossing the Forbidden Zone

Our grandfathers turned to the land for answers in an agrarian era and our fathers to industry in the industrial era. But where do today's community leaders turn for answers in a knowledge-driven era? Instinctively, they have turned to our universities and said, "Grow some intellectual products! Let's get to work creating jobs and wealth so we can improve the quality of life for our citizens."

That's where they discover the forbidden zone. The cultural gap between traditional academic institutions and the economic marketplace is too wide. Like the junction in the solar cell, this forbidden zone makes it far too difficult for marketable ideas to find their way out of university laboratories. The approach to solving this problem must be like Kilby's in tapping solar energy—a departure from the norm.

The question becomes, do we redesign the system or design a new one where intellectual-based products can find their way out of a zone in which they exist in abundance but where they have not been transferred into products for society? Why has this been the case?

After wrestling with these issues in a traditional academic setting, I finally concluded in the mid-1980s that we can't just redesign the system. We have to design a new one—the missing piece. We have to come up with a whole new "cell."

My learning curve about this cultural forbidden zone began with my efforts to transfer the photovoltaic technology to Texas Instruments. I managed to get Texas A&M to make an exception to the rules at that time, but it was not done easily. It created measurable stress among my own colleagues even at a "practical" institution like Texas A&M that already was serving its constituents well as a land grant, sea grant, and space grant institution. (The concept of becoming an "intellectual product" grant institution had not occurred.)

At the same time in the 1970s when Stanford Research Institute was spawning Silicon Valley and North Carolina was building the Research Triangle, not one institution in the State of Texas had a policy that allowed a private source of funding to own or license the intellectual property that resulted from its sponsored research. Even today, profit is a controversial issue on most university campuses. This culture only serves to widen the forbidden zone associated with moving technologies into the marketplace where they can become profitable products that serve society.

The fundamental reason lies in why one pursues knowledge. In the university community, knowledge is an end, not a means. To further compound the problem, public universities argue their responsibilities to tax payers: They paid for it and should therefore share the research results. The problem with that idea is that it doesn't recognize the added financial and management investment required to get the idea to the product stage. Giving it to the public actually prevents the additional investment required to convert solid technology into marketable products. If any business, university, community, state, or nation really wants its citizens to benefit from state-sponsored research, then that institution had better find a private sector partner who understands the difference between a wonderful piece of technology and a marketable product. Plus, that partner must understand the rules of technology transfer and the role that collaboration can play.

By 1985, I decided to pursue the notion that a new culture was needed to help navigate new intellectual properties through the forbidden zone. I have since learned that the conditions that surround the creation of such a culture are in themselves quite unique and vary depending upon local circumstances.

Chapter 4
Whatever It Takes

In 1982, Austin, Texas, was known mostly as a country music haven and a college football town. Ross Perot was best known as the Texas billionaire who created EDS and rescued his employees from Iran.

I was directing the Texas Engineering Experiment Station at Texas A&M when Texas joined in the nationwide scramble to attract the first American based, private-sector initiative to battle the growing Japanese control of the computer industry. The nation's electronics/computer community had cleared a major hurdle in deciding that it needed the Microelectronics and Computer Technology Corporation (MCC). MCC was the brainchild of Bill Noyce, chairman of the board of Control Data Corporation in Minneapolis.

It was a call to arms that asked American computer companies to pool resources, technology, and talent to compete with Japan's growing competitive capabilities in fifth-generation computing. In many ways, this was a proactive strike by industry rather than a call from the government sector to rally arms against an outside competitor. This foe was not a national or government foe as in a war of soldiers. Instead but it was an industry foe (the Japanese government) in a war of technology.

A lot has been written about MCC, and the interested reader can find many articles and books relating to it. It was Bill Noyce who led the charge and was ultimately successful in rallying companies within that industry to form what became MCC. American companies had responded in much the same spirit as this government had when the Russians launched their first satellite Sputnik in the fall of 1957. The space race had begun. To save America's national pride and to protect itself from the threat of space-born missile attack, America launched its own satellite program. Shortly thereafter, the United States passed the National Aeronautics and Space Act of 1958 which established the U.S. space agency and appropriated what eventually totaled hundreds of billions of dollars to support the Mercury, Viking, and Apollo space projects. The United States topped its foe when on July 20, 1969, astronaut Neil Armstrong became the first man on the moon—planting an American flag on its surface.

MCC is a benchmark of how industries that typically compete with one another can pull together to fight for economic survival. My point is simply to say to every community and to every individual that the global economy is here, and that we are all equipped with the most formidable tool to survive and yes, flourish, in this economy: the ability to think. When individuals develop that capability and produce knowledge and collaborate with one another, the community will be strong.

Creating, attracting, and retaining top talent should be the goal for every community. The challenge is to do it for economic gain. How does one organize, attract, and manage this intellectual asset to serve the community as a whole? This, in my judgment, requires offense, not defense. It requires a leap of faith. It requires experimentation. It requires risk taking, and we all know in our free enterprise global community there can be no success without the risk of failure. Sometimes we fail forward.

MCC provided an opportunity to learn. The state had decided that Texas had to win it. Governor Mark White asked Ross Perot to lead the business group and me to lead the technical group to form a Texas team to recruit MCC to the state.

The atmosphere was charged with expectation on a bright spring morning in 1983 when the MCC Site Selection Committee gathered for a quail and gravy breakfast at the LBJ Library on the University of Texas campus in Austin. The race, by this time, had been narrowed down to four locations: Austin, Raleigh-Durham, Atlanta, and San Diego. When our team stood before the MCC group to represent Texas business interests, we had already made our leap of faith and we told them: “MCC isn’t something that would be nice to have. This is something we have to have. So whatever it takes to get it done, that’s what we’re going to do. So, now, what does it take?”

First, there were turf battles to overcome. Multiple cities in the state wanted MCC. Because of the selection criteria, it was narrowed down to Austin, predominantly because of a requirement that a major university be accessible to MCC.

It also required that Texas A&M and The University of Texas at Austin work collaboratively to make available the electrical engineering and micro-electronics talent necessary to insure MCC the technological resources they sought. It also required cooperation from San Antonio, which had a winning proposal in all aspects other than the presence of the type of educational institution that was needed.

San Antonio put its plan on the table for Austin to use, which Henry Cisneros, then Mayor of San Antonio, did with good heart. It required a group of cities and individuals in a state known for rugged individualism and hard-fought, head-to-head competition to circle the wagons and pull together to find the basis for dealing with a changing world and new opportunities.

I had the privilege of being a member of a small group in the Governor’s Mansion that Sunday evening when we began to lay our strategy. I had the privilege of heading the technical team in making the presentations to MCC.

Today, more than 15 years after that commitment and Texas’ winning bid for MCC, a once-sleepy university town has grown to become one of the high-technology capitals of the world. Dell Computer, IBM, Motorola, and scores of other technology companies have established an enormous presence in the city. How much of that growth is attributable to the state's success in attracting MCC? A better question might be: How much of the growth stemmed from the dedication of the leaders of Austin and the State of Texas to create a center for technological innovation and commercialization? What would it be if we hadn't?

I contend that Austin's transformation came about as a combination of many factors, but mostly it was due to attitude. After all, there was little direct benefit in the way of jobs and economic stimulus from the physical addition of MCC. People began to notice Austin and its efforts and those who paid the greatest attention were the decision makers looking for a place to locate their technology-oriented businesses. They saw a community ready to embrace them, people who understood what they were about. When they took a closer look, they discovered a charming Texas Hill Country city with a high quality of life and a great educational system.

So, what led to all of this? The leaders in the State of Texas, and Austin in particular, recognized the need for the development of a knowledge-based economy and intuitively knew that this wasn't "just something that would be nice to have."

The MCC experience helped me see how community leaders can work together to build win-win partnerships. Now I had a road map to go after a prize as large as the $10 billion Superconducting Super Collider, a facility with the potential for outstanding technological breakthroughs.

We all know today that the SSC was indeed located in Texas. Again, it was an honor serving as a member of the Governor's team that developed and implemented the strategy that won the SSC. In the aftermath of the tragic cancellation of the project, I still believe that the experience gained will pay meaningful dividends to the state. One of these dividends was helping to build HARC, which put together Texas' technical team to compete for the magnet design.

The underlying theme here is culture change—where people who have been comfortable living one way are now faced with exciting new opportunities. As we know, however, change never comes without risk.

Chapter 5
The New Business Paradigm

The world is a vastly different place from the way it was during the post-war 1940s and 50s of my childhood in Irving, Texas. Growing up in and around my father's shoe repair shop, I spent my Saturdays riding past fields of cotton and cattle during our ritual, cross-country trip to buy cowhides at Tandy in Fort Worth. Weekdays were easily spent listening to the idle chatter of townsfolk at the local drugstore.

In those days, the talk would drift from town gossip and politics to weather and the price of crops. To a small town boy growing up in this southwestern environment it seemed that there was a natural order to things. Life was predictable and change was mostly related to growing. In this era and certainly in what I'd call "the small community environment," the rule of life was get educated, work hard, get a job, hold that job for life, be punctual, be honest, have integrity, retire, get your gold watch, and play with the grandkids. In most households, the husband worked, and the wife was a homemaker who stayed at home and raised the children.

Church was a big part of community life. There was no television, and there certainly weren't any 24-hour news programs. One received world news on occasion, but it didn't seem to matter much unless it was a war which would mean that some of the men in town would have to go and fight. One of the most exciting things in Irving was Little League baseball and the Parent-Teacher Association was as important as summer in the park.

There were a lot of farmers' markets where one could buy locally produced goods that families would load in their trucks and drive in to sell. There were also town meetings where any issue of importance to a community could be discussed by all involved and resolved in a way that generally served the best interests of the community as a whole.

My father's shoe repair business on the town square was about three blocks from our house. I would often ride my tricycle or walk with him into town—more specifically, I would skip because he was a tall man and hence, my nickname.

We almost always knew everybody, and when children were riding their bikes, people in their cars would watch out for and take care of them. I knew most of the old men who sat on the ledge at the drugstore, where I would often hang out and listen to talk about the weather and the crops, and, if it was an election year, some of the politics. The pace was different from that of today, and the coins of the realm were land, cotton, cattle, oil, and gas.

Unless someone came up with a new tool or a new piece of technology to make life easier or more productive, the process of farming remained the same. When something new did come, the initial response might have been skeptical. But if it worked, it rapidly became an accepted part of a community whose members swiftly embraced it, recognizing the benefits that were going to accrue. They didn't call these things paradigms at that time.

These days, that bucolic little North Texas town has been swallowed by the urban sprawl of the Dallas-Fort Worth metroplex. A drive to Fort Worth now would put you on the path of several million people, and you would be hard-pressed to find a cotton field along the way. People chatting on the square in modern Irving are more apt to talk about the price of computer RAM than livestock. Their shoes are more likely to be made at an automated factory in Taiwan than in Texas, much less at a little cobbler shop in Irving. Today, the financial well-being of my hometown—like that of every other community in the world—has become entangled in an increasingly global, technologically driven marketplace.

A fundamental shift has occurred. These are the good old days.

Many of those who recognized this shift early on have sought ways to capitalize on it for the benefit of their communities. They conclude, correctly, that communities that adapt to the new economic order will be the ones that survive—and thrive—in the emerging knowledge-based economy. Yet, even those who recognize these changes are often overwhelmed by their scale and uncertain of what they can do to tap into this new economy.

Many are in the same situation as those turn-of-the-century leaders who saw the arrival of the automobile and recognized the onset of a great new era. They didn't know exactly what was coming, but they knew it could bring prosperity if they could get a piece of it for their own communities. Those communities that created the right environment and incentives for industrial development were the big winners of the 20th century.

In the United States, when the quality of life was based upon what was raised or grown on the land, communities naturally turned to the land and the government created land grant college systems with agricultural research and extension services to provide support. When we entered an era where our quality of life depended primarily on industry and what was manufactured in the steel or automobile or airplane plant, we focused on the industrial sector and created engineering research and extension services to support industry. Now, as we move into an era where the quality of life depends upon our intellectual products and our ability to create and use them, what will we do to stimulate and support this new kind of knowledge-based product?

After 30 years of working in private industry, government, and academia, I am finding that many of our existing institutions are structurally and culturally unsuited to respond to these new economic needs. Any community that wants to be competitive in and help shape our technology-driven global economy will not succeed by simply turning to their universities, governments, or business institutions alone.

Most of us have seen the challenges that communities face when trying to establish a new mechanism or process that will permit them to tap into the intellectual resources of their universities and to attract other talent that will help the community succeed economically. While most communities turn to their universities for this purpose, the universities are uncertain about whether their role should include stimulating the economy. Their priority is to create new knowledge. Most often they are not skilled or interested in gaining commercial value from that knowledge.

The problem is somewhat different for business. Indeed, in a depressed economy, many companies are paring down, even in their core business. Yet, they need to have their technology base refreshed. They need to stay at the cutting edge and seek new ways in which they can access that technology without having to bear all the associated research costs.

We need a “fourth culture” that adds value to knowledge through the interaction and collaboration of industry, university, and government partners. While the MCC model is relevant, today’s competitive environment requires that we go beyond that. We need to create a culture based on collaboration.

About 98 percent of the people in our government, industry, and university laboratories may not be able, much less willing, to participate. Typically, however, the remaining two percent—the “two percenters” described in Chapter 9—will have the energy, desire, and entrepreneurial spirit that is needed. Many already seek alternative avenues. If we create an environment where even half of the two percenters can collaborate on projects of mutual interest, this fourth culture would evolve.

The challenge, then, is to create a center that permits, encourages, and rewards talent from university, industry, and government to come together for the purpose of creating value from technology. This center must also possess the financial, marketing, and management skills necessary to ensure that technology gets in the hands of the right private-sector entities so that it will serve the community. This critical mass of talent working to accomplish those goals is the Center for the Performing Sciences.

It is important for even those who don’t participate in this center to recognize its value. Even when faculty members of researchers from industry and government have the freedom and flexibility to do curiosity-driven research and to teach, they must finally ask where the money comes from that supports their institution.

In a free market, it comes from the hard work of some group of people or even an individual who created a product or service of value for which others in the market were willing to pay. If there aren’t any profitable industries, there aren’t any jobs; and if there aren’t any jobs, the individuals and companies aren’t paying taxes. Consequently, a profitable industrial base pays taxes, creates jobs, and hires the employees who also pay taxes. These tax dollars circle back to fund the public, academic, and government institutions where those who want to pursue scholarly endeavors and curiosity-driven research have the means to do so.

The feeding chain begins with a healthy economy which pays for the university-sector as well as the government-sector. Let’s not be naive about the chicken and the egg. A Center for the Performing Sciences is responsive to an industrial sector that now needs to down-size to remain profitable but still needs to retain its competitive edge through intellectual property and talent.

Places like HARC can accommodate this need. For example, in 1995 Texaco, faced with downsizing its R&D, decided to donate its geochemistry laboratory to HARC. Rather than closing the unit down, Texaco partnered with HARC with the goal of getting four other companies to join in supporting the lab’s R&D projects. In this case, five companies pay 20 percent of the cost rather than each doing its own research and, in essence, funding 100 percent. The benefit? Each shares in the ownership of the intellectual property at one fifth the cost of doing it independently.

As the talent pool is enriched through collaboration, the quality of the intellectual products they are getting at a fraction of the cost may indeed be better. The primary difference is that each one of the five knows the other has the same technology in a certain area. They don’t have to compete to create it, but instead compete in its application. The term “coopertition” has emerged at Texaco. HARC manages the cooperation process and the free-enterprise market takes care of the competition.

A Center for the Performing Sciences can help technology-based industries find new ways to collaborate and reduce the cost of creating technology. Another recent example led to the creation of a new company named Genometrix. The Department of Commerce awarded members of a tri-state consortium $9.2 million in matching funds to develop automated DNA chips that could speed the tedious process of DNA sequence analysis. HARC played the lead role in organizing the team which included Baylor College of Medicine, MIT, and HARC as well as private sector members Beckman Instruments, Inc., MicroFab Technologies, Inc., Laboratories for Genetic Services, Inc., Genosys Biotechnologies, Inc., and Triplex Pharmaceutical Corporation. The collaboration worked because each member had something unique to contribute: the Department of Commerce (through its Advanced Technology Program) had the wherewithal to provide the matching funding; MIT and Baylor had the research talent and technology; Beckman and the other companies had the ability to develop and market the products as well as invest the required matching capital; and HARC had the experience and mission to bring the parties together in an environment that rewards collaboration. As a result, Genometrix spun out of HARC and will supply Beckman with neural-network based chips for their instruments. Baylor College of Medicine, MIT, and HARC each own equity in Genometrix and receive research support. It can work!

Chapter 6
University Tradition Runs Deep

Consider the Pacific Northwest salmon which spawn in freshwater, migrate to sea to grow and mature, and return to their natal streams to reproduce. The salmon population is threatened today not just by an occasional bear who snatches his daily catch, but by the rate of human population growth and economic development.

These salmon don't really need more spawning grounds. They need better hatcheries, richer nutrients and cleaner streams to get them to their next stage of life. The same might be said for the spawning grounds of technologies—our universities. What is missing is the hatchery that can nurture these ideas and send them out on their own—readying them for a business or company which then develops them for market.

In a broad sense, the economic eras of Texas are not that different from any other region of the world. Back up far enough in time, and you'll find a Texas where great wealth was related to land ownership—the ranch or plantation. Raising cattle or cotton were the true symbols of wealth in an agrarian economy. The land grant university system, as envisioned during Lincoln's presidency and enacted under the Morrill Act, was not established simply to educate the state's sons and daughters. It also was intended to provide farmers and ranchers, who were the backbone of the economy, with the latest technology on improved strains of seed or cattle.

During that period, if new technologies and information were to reach the economic drivers throughout Texas' rural communities, then a new mechanism had to be created at the University to help sell the state's beef or crops. In Texas, as in many other places, this was accomplished through the creation of an agricultural experiment station and an agricultural extension service. In Texas both were housed within Texas A&M University's College of Agriculture. (More than 100 years later, these institutions still serve under virtually the same model.)

In 1914, the Texas Engineering Experiment Station (TEES) was created, in a sense, to help the state deal with the transition from an agrarian-based economy to an industrial-based economy.

In Texas, this function was set up as a part of the land grant institution, in the Texas A&M University College of Engineering, and historically was directed by the dean of that college. Like their counterparts in agriculture, these organizations, until recently, operated in much the same way as when they were founded.

Several years after the Institute for Solid State Electronics at Texas A&M was up and running and Jack Kilby had gone back to Dallas with another patent under his belt, I was asked to head the Texas Engineering Experiment Station at Texas A&M. It was during this period that I would learn how wide the cultural "forbidden zone" is within academia as well as between academia and the private sector. It was also the time when I began to understand how the historical influence of our existing institutions inhibited them from adapting to new economic realities.

So it was in 1980 that I took the helm of a 66-year-old institution created as a sort of technology-transfer arm of the state some 45 years before the first integrated circuit was developed. My mandate from the A&M Board of Regents was to expand this locally operating institution, which directed the work of 26 research divisions, into a statewide entity that would better serve the larger community. We grew TEES from a centralized $3 million annual research operation to a $30 million annual interdisciplinary operation with outreach locations in North and South Texas.

Even with this growth in funding, TEES was only slightly better equipped to deal with the changes that were driving the information revolution emerging around us. Indeed, as recently as 1980, the state's public universities had not yet developed policies for dealing with intellectual property issues. I remember well the discussion about intellectual property and technology transfer issues at university system executive committee meetings.

"Skip," the director of the Texas Agriculture Experiment Station said to me during one of these discussions, "the way we transfer technology over here in Agriculture is you just call your neighbors and tell them you've got a sack of that new hybrid seed out on the front porch and to come by and get a cupful."

"When we developed a new microchip over at Texas Instruments," I replied, "we sure didn't call Motorola and tell them we've got them on the porch and they ought to come by and get a cupful."

The same fundamental view would often emerge within the academic community in arguments about public-private partnerships in technology development and transfer, the idea that a tax-supported public university must share research results equally.

"Don't all the citizens pay equally to run this place?" someone once asked me during one of these exchanges.

"Yes. Everybody's taxed and then Texas A&M gets the money from the state."

"Then doesn't everybody own it?"

"Well, yes."

"Then how can we let some one person or company come in here and buy it, since everybody owns it? Shouldn't we just give our work away to society?"

"Well, no."

It is a satisfying, simple argument, but it simply doesn't work that way. Someone has to put a huge amount of money at risk to create a marketable product out of a new technology. We could uniformly tax everyone to do that, but, if we did, we would essentially be applying an economic model that has already failed. What was that system called?

These issues are still being debated. The roots of university culture run deep and are firmly established. It is difficult for the average citizen to understand the "forbidden zone." Progress is being made in addressing the issues and policies dealing with technology transfer to the private sector. The debate about what role our universities should play, however, continues, and time will have to pass before a clear picture emerges, particularly for the publicly-funded institutions.

Chapter 7
Profit is Okay

Historically, communities have taken great pride in recognizing, celebrating, and promoting their universities. The university community has reveled in that attention and respect. Today, communities are asking for reciprocity.

Communities are now looking at their universities and expecting them to give back more—to spawn a Research Triangle Park or an incubator. They want their needs addressed and they want the economic value that can be spun out of the human mind.

The reality for today's academician is to understand the responsibility of being relevant, not just respected.

The disconnection between my arguments and the established thinking inside Texas' higher education establishment in the early 1980s was not just an academic phenomenon. It was a reflection of a society still grappling with new ways of thinking as our world shifted into a new economic model. Our society is still struggling with this transition today.

Consider the debate in the United States within the last few years over farm policy, or—as it was argued at the federal level—over the issue of "parity." Just as we're discussing new ways to privately support the creation of intellectual products, our government continued to ask such basic questions as, "What are we going to pay our farmers to grow–or not grow?" I use this point not to criticize farm policy, but to illustrate the complex policy and cultural issues that are under stress because of the current economic transition.

A recent program aired over National Public Radio focused on the farm policy debate. The discussion centered on the issue of an "advanced deficit payment" for farmers and went something like this: If a farmer is going to grow a crop that will cost more money to produce than it can be sold for—a deficit—then the government will go ahead and pay that deficit amount in advance to the farmer.

Now, with the advanced deficit payment in hand, the crop is grown. The market changes, and the crop sells for more than the farmer and the government expected. Suddenly, it turns out there is no deficit after all, and now the farmer owes his advance payment back to the government.

But then the federal government says, “Well, he’s already spent it and he had these other expenses and such, so let’s forgive the advanced deficit payment.”

Agriculture was, and remains, an important part of the university curriculum at Texas A&M and during my years as director of TEES, I tried to explain to my colleagues from the agrarian culture why the university needed to have policies that allowed privately owned research at the university as well as the sale of university-developed technology to the private sector. Unlike farming, I explained, there were never advanced deficit payments against the crop of semiconductor chips to be “grown” at Texas Instruments. In fact, it simply would never have occurred to anyone in the technology sector to ask the government for that kind of help to keep the laboratory running.

There will always be, and probably should be, certain services and/or products in a community that are guaranteed. The fact that most people need transportation and, hence, that roads need to be built and paid for by the community is an example. But that has not prevented toll roads from cropping up in a private-sector competitive mode. Some also argue that medical services, utilities, and other services should be provided to all. Governments will undoubtedly continue the debate over which essential services should be provided, regulated, or privatized.

When it doesn’t work to control a service, like communications or the airlines, we deregulate them. The deregulated utility industry in the United States alone is creating a $300 billion annual competitive market. Companies like Enron are emerging that aren’t producing gas anymore. They are trading gas and are going into the business of trading kilowatt hours.

When we deregulated the communications industry not so long ago, it created very competitive industries and companies within industries to provide services or products. In a very fundamental way, what happened in the early 1980s at institutions like Texas A&M was a case where a land grant institution with a strong agricultural school and a strong military program served the state primarily through government funding.

Everybody has to eat, so shouldn’t the government guarantee the farmers a profit since they were taking enormous risks to grow these crops? Our country had to be defended, and the university has a program that trains military people to defend the country. This culture of community service for the good of all is difficult to change in a free-enterprise, competitive marketplace where one must invest and could lose it all.

There wasn’t a sense that everybody needed to have an integrated circuit, and, therefore, those who grew them were not guaranteed a profit. Today, that view might be different!

It’s in that context, that spirit, that sense of change, that I found myself as a member of the Executive Committee of a traditional university system arguing that the system needed to have an intellectual property policy to allow just one of these free-enterprise companies to make the investment, take the associated risks, and assume the ownership so they could turn a technology into a profitable product. If successful, society would benefit. It was unrealistic to expect any single company to risk the capital if it didn't have the parallel opportunity to benefit.

This university had to find its way to participate in that process as effectively as it had found a way to participate in supporting the soldiers to defend the nation. The mission is to serve the common good; the challenge is changing the way it is done. Centers for the Performing Sciences will help.

At the core of making the leap of faith that a community must take to play this high-risk game is the need to approach matters in ways that are historically different, but still exist for the common good. Public/private partnerships may be the best way.

My argument then was, "Look, let me tell you why Silicon Valley is Silicon Valley. Stanford and SRI are there. They sell their technology to companies like Hewlett-Packard and to the venture capital community, which then put tens of millions of dollars at risk. The investors may lose it. There are no guarantees. But they aren't willing to take the risk unless they can own the upside potential as well.

"We simply have to sell this technology. And that means we need to have a user-friendly intellectual property policy."

Texas eventually managed to get these policies in place for its universities during the time Jack Kilby and I served on the Governor's Science and Technology Advisory Council. I finally recognized the necessity for new, private institutions created with the specific mission of transferring technology.

It was probably obvious, but what I failed to recognize was that the university has a culture that is resistant to this new role. It goes beyond the university's basic mission of teaching, research, and service. It surpasses the individual's desire to create knowledge as an end without having to engage it as a means.

The mission of the university first and foremost is to educate. It attracts bright people who are motivated to go where their minds lead them, not where the market leads them. It gets back to the old question of "technology push versus market pull." Realistically speaking, the faculty of a university can't be pushed or pulled anywhere by the marketplace or for that matter, by the university president. A valid question to ask is, "Do we really want that to change?"

I can't predict how well the traditional university will do in our new knowledge-based economy. I can say that the need for distance learning, to reduce the costs of operations, and to compete for fewer students will force the institutions to change. New opportunities for the private sector to engage in teaching and training will emerge. Motivated by industry's need for skilled workers, individuals and companies will find ways to teach skills more effectively and efficiently than the way it has been done. While the classical focus on teaching our sons and daughters to think should never change, the mechanism by which it's done will change.

The greatest threat to the future of the academic institution comes from those institutions whose faculty feel that the institution is there to serve them as opposed to the inverse. For, in the final analysis, serving our community and participating in a healthy economy must be the mission for all institutions. When that happens, everyone benefits.

It is a privilege to turn out learned individuals capable of thinking and confident that society will value their intellect and abilities.

No place, other than the family itself, has a better opportunity for establishing that understanding and putting it in perspective. I don't believe, however, that the traditions of universities will permit them to change fast enough to truly help industry take full advantage of the knowledge required in our competitive economy.

Universities should stay focused on producing thinking people and conducting R&D to keep the faculty at the cutting-edge of their disciplines. This is particularly true for publicly-funded universities. What is also needed is a new mechanism that brings the two percenters from academia, industry, and government together to push at the forefront of knowledge creation and knowledge utilization to define, distribute, and quantify this new coin of the realm.

Consider the motivated and intelligent person who chooses to become a college professor, versus a classmate who decides to risk it all on an entrepreneurial start-up. The one who pursues a life in higher education typically is driven first by his contribution to the community. He gives up the long-term financial potential his classmate pursues and is motivated, instead, by the long-term stability and security of tenure and the pursuit of ideas. With his security, he is able to enjoy the intellectual freedom his profession offers.

If the development of intellectual properties in science and technology are needed to stimulate economic health, a community should be developing new tools to perform this work. It shouldn't be forcing an unwanted role on a faculty that is unmotivated by market issues. Not only is the culture too distant from the task at hand but also one runs the risk of de-focusing the university's primary mission by trying to force this new role upon it.

If a parent brought his high school senior to the university to learn about admissions and academic programs while another individual came pursuing a technology-based idea, who deserves the university's greatest attention? Is it reasonable to expect the faculty to respond well to both requests? Are they organized to do both?

Perhaps it is better to create institutions that are specific to the task—Centers for the Performing Sciences—and use their unique mission to attract that small percentage of faculty members who are willing and able to play the technology transfer game.

Chapter 8
The Leap of Faith

I’ve talked a lot about why a “community” must recognize the need for a new knowledge-based, economic development entity, but, the fact is, it’s usually only a handful of people who drive themselves and the community toward this vision. I’ve been privileged to watch some of these leaders in action, and even though every situation is unique, there is a commonality to the process they follow once they decide to meet the need.

The common element is this: None of these people have a clear idea of exactly how to accomplish their vision. It is a process of discovery. However, without fail, they sensed the need for a mechanism that would tap into the emerging knowledge-based economy. They explore, seek, and probe to figure out what one should look like and how it’s going to work. This open-minded pursuit yields solutions based on the unique nature of these leaders and the realities of their communities. In fact, this discovery process often extends well beyond the initial creation of a new entity. Indeed, Centers for the Performing Sciences must be evolutionary creatures if they are to thrive.

My earliest experiences with this kind of leadership came shortly after I arrived at Houston Advanced Research Center in 1985. The visionary and financial force behind HARC was George Mitchell, a Galveston native and son of a Greek immigrant, who started a company with a used drilling rig and discovered a huge natural gas reservoir in North Texas. George had developed a passionate interest in the idea of sustainable development and was putting his ideas to practice with his company’s development of The Woodlands, a 25,000-acre planned community in the pine forests north of Houston.

In 1974 George and his wife Cynthia assembled a group of business and academic leaders who shared a common concern about global issues. Together, they forged plans for a multi-year program to seek solutions. The resulting Woodlands Conference Series launched the following year brought together hundreds of the brightest minds in business, politics, and education.

The Woodlands conferences and international essay competitions laid the groundwork for what was to become the Center for Global Studies—the policy research division of HARC that today focuses on global environmental issues, sustainable development, and the social and policy implications of science and technology.

As the conferences grew in stature, many of the state's major universities stepped in to provide leadership. George was fascinated by the synergism that is created when businesses, government representatives, and academicians work together to produce something greater than the parts. Mitchell's interest grew in institutionalizing this kind of collaborative effort.

"I believed if we could get the state's major research universities to work together on projects they couldn't do individually," George has said, "and if their top talent could meet with the government and private sector in a collaborative atmosphere, it would help get research into the marketplace more quickly."

He also believed that The Woodlands, Texas—the home of his planned community just north of Houston—might be an ideal site for a research forest and a university consortium.

George began working with Texas A&M University, Rice University, and the University of Houston to establish the Houston Area Research Planning Committee. The group awarded a contract to Arthur D. Little, Inc. for a feasibility study in early 1980. The study looked at all of the major research institutions that had spawned knowledge industries, such as Silicon Valley near Stanford and Route 128 near MIT. The one that enamored George most was North Carolina's Research Triangle, a planned research park created in 1959 by leaders from business, academia and industry to attract companies doing world-class research and development in growing scientific areas. The Park's greatest attraction was Research Triangle Institute, where interactive research was carried out by talent from Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill. The planning committee's report of December 1980 concluded that The Woodlands was a viable location to establish a center in basic, applied, and policy research funded by contracts, grants, and gifts.

After more than a year of additional planning, Mitchell approached the boards of Rice, Texas A&M, and the University of Houston inviting them to join in a collaborative research facility that would pool the capabilities of those institutions. On September 7, 1982, a partially assembled board of directors of what was then called the Houston Area Research Center met at the Houston Club Building in downtown Houston. They agreed to develop a mission statement and an organizational charter and to create an executive committee.

It was recognized that HARC could be the catalyst for new research that one institution alone could not achieve and the institution set out to create a model that would integrate the diverse cultures of private industry with institutions of higher education.

Much had been accomplished by the time HARC's board met on April 7, 1983, at the headquarters of Mitchell Energy & Development Corporation in The Woodlands. University of Texas System Chancellor Don Walker telephoned Mitchell during the meeting to express interest in joining the new consortium.

George came to view HARC as the intellectual hub for what eventually was to become The Woodlands Research Forest. Both RTI and HARC anchored real estate developments.

By 1985, we had found some projects to pursue. HARC had established the Texas Accelerator Center and began work on superconducting magnet designs for application in the Superconducting Super Collider project in Waxahachie, Texas. Another project was to establish a supercomputing center, and although HARC just missed the cut to become an NSF National Center for Excellence in Supercomputing, we decided to pursue a center anyway.

George and I were exploring what HARC would become and how it could work as an economic development tool as we traveled together to Minneapolis during the summer of 1985 to visit Control Data Corporation. We spent the morning touring the company's supercomputer division and hearing the story of their liquid nitrogen cooled system. But it was a casual conversation between George and CDC Chairman Bill Norris that marked the most memorable moment of the day.

After we arrived at the CDC board room for lunch, George and Bill stood at the floor-to-ceiling windows that overlooked downtown Minneapolis and the sprawling university and medical center complex below.

The conversation went something like this: "You guys have really done a good job up here," George said. "Your universities have spun out all this medical technology and you've got this huge medical complex and all this activity going on here. How did they do that?"

Bill turned to George and said, "Hell, they didn't do that. Those guys didn't transfer the technology. We had to go in there and pull it out."

Bill's statement has great significance for anyone hoping to create their own Center for the Performing Sciences. What Bill had described was that same "forbidden zone" I had encountered from the academic side. Part of recognizing the need for a new tool is to recognize the limitations of those you already have.

Chapter 9
The Two Percenters

One of the first issues faced when building a new institution is: Who's on the team? Do you pick the people first and let them direct the evolution of the programs, or do you pick the technology and then find the people to fit those particular areas?

One can argue that a little of both is needed. But, in either instance, exceptional people—whom I described in chapter five as the "two percenters"—must be recruited. These individuals want to do more than their current careers in industry, academia, or government can allow. They are driven and excited by seeing how research can be turned into a product and how that product can be commercialized and marketed. They are motivated by the process of collaboration.

The challenge, then, is to create a center that permits, encourages, and rewards talent from university, industry, and government to come together for the purpose of creating technology and gaining value from it. This center must also possess the financial, marketing, and management skills necessary to ensure that technology gets in the hands of the right people.

In the first instance the institution needs people motivated to use their intellect to build the important technologies that can have a bearing on the future economic health of the community. Here, it is seeking relevant scientific excellence.

In the other approach, there are technology areas that are critical to the community. In this case, the institution will want to take advantage of these market opportunities by developing further capabilities. Today, for example, HARC is developing superconducting magnets for energy storage to aid independent power producers in "wheeling" electricity through interconnected transmission grids. The magnets were first developed for use in controlling the proton beam in the SSC. In instances like this, having people on board who are excited about their own specialty and who have a sound technical basis for developing forefront technology makes it possible to take advantage of an emerging opportunity. Ultimately, bringing in people who are passionate about their work will provide a competitive advantage for the center, and for the community.

Since the mission is to see that science performs for society (rather than simply for the intellectual stimulation of the individual), another consideration is the need for “cultural matching” in the selection of people. By this, I mean that it is important to seek individuals who come from a culture or can easily adapt to a culture where they are motivated by and attentive to how the community is going to benefit from their work. This is contrary to the traditional “scholarly” approach where the institution seeks individuals who are motivated by following their own intellectual pursuits and then hopes that what’s interesting to them can be published. The thought that their work can be put to use by somebody, somewhere, sometime is left to chance. The only issue is scientific excellence.

This, of course, relates to the historical debate in the intellectual community concerning the relative value of “basic” versus “applied” research. Today, we debate the relative value of “R&D” versus “services, testing, and evaluation”—intellectual purity versus commercialization.

In reality, an enormous opportunity is missed when we don’t pay attention to both. If researchers developing a specific product will listen to the research results, they are likely to discover new, fundamental knowledge. Conversely, if those interested only in pursuing basic knowledge will follow where the research leads, new applications will become apparent and great products will be discovered.

It’s amazing what you can hear by just listening to the experiment. No matter what your intent was when you entered the laboratory, the experiment will “scream out” a result most likely never anticipated. Galileo Galilei, the first person to apply the scientific method to nature, recognized the process in his autobiography: “When a person has discovered the truth about something and has established it with great effort, then, on viewing his discoveries more carefully, he often realizes that what he has taken such pains to find might have been perceived with the greatest ease. For truth has the property that it is not so deeply concealed as many have thought.”

Galileo was quick to add, “Yet it often happens that we do not see what is quite near at hand and clear.”

My own experience doing research both as a physicist and as an engineer has shown me time and again that when I design an experiment to discover a fundamental secret of mother nature, she will unveil a very practical real-world application. The inverse happened while trying to improve the yield of integrated-circuit manufacturing and discovering the conditions for dislocation-creation in silicon. That formed the basis for my doctoral dissertation.

So, the debate of whether to select individuals who do strictly basic versus applied or development versus service, testing, or evaluation, wears a little thin. The best team members are those special people who share a common desire to observe what the results are saying and who are motivated to follow-up by asking how the results can perform for society.

A historic case in point occurred on April 6, 1938, when Roy J. Plunkett, a DuPont chemist, accidentally made the first batch of what would later be known to us all as Teflon®. He was experimenting with different gases to create a better coolant. One morning he found that the gases left in a container overnight had escaped and in their place was a white, waxy solid. Plunkett's scientific curiosity led him to think of this not as a "botched experiment" but as an opportunity to investigate a unique material which was later found to be impervious to a number of corrosive chemicals, extremely heat-tolerant and stick-resistant. The discoveries of tetrafluoroethylene resin (FEP) and later polytetrafluoroethylene (PTFE) were purely accidental and it was another ten years before a practical application was found. Yet, by asking how the invention could perform for society, Plunkett and a host of others at DuPont who followed found numerous applications—products that have benefited mankind and that have helped make DuPont one of the world's largest and most diversified chemical companies.

Discovery must be at the core of the institution. In that sense, those individuals and institutions who are dedicated to making science perform for society are the perfect complement to the scientists and engineers in academic settings, where the traditional goal has been to add to the knowledge base, and to those in government laboratories, where the original purpose was to develop technologies for government use in national service. (Today, our federal laboratories are encouraged to look for commercial applications for technologies once developed for security purposes. However, it will be challenging for them to cultivate a culture where intellectual property is protected, licensed, and transferred to the private sector.)

When creating a Center, it makes sense to recruit talent (the two percenters) from both universities and government laboratories and to maintain relationships with their institutions in order to help develop a culture that can take economic advantage of technology originally created for other purposes.

Individuals from industry must also be involved. They already know how critical commercialization is to the company's survival. Those individuals who work for a particular company in an established industry need to get involved in a Center where they can be stimulated by multidisciplinary interaction and collaboration. They will find both talent and technology.

HARC's staff has also grown as a result of acquiring talent through the downsizing of industry R&D. Texaco, as mentioned, recently donated its geochemistry laboratory to HARC. With the laboratory came all of its intellectual property, equipment, and eight researchers. Formerly working for a single company, these geochemists are now making their services available to a consortium of companies that participate in HARC's energy research. Where they once worked in isolation under "strictly-proprietary" conditions, they are now interacting with colleagues from other industries as well as from government and universities.

The value to society is evident: People who might otherwise have been terminated are continuing to work, the parent company benefits from the research at a reduced cost, and other companies, which might have had no in-house capability, are now sharing in the lab's services.

Finally, a Center for the Performing Sciences needs bright people willing to embrace other cultures and to explore other applications for their own intellectual products. Galileo had to overcome cultural problems of the forbidden zone when he developed the telescope. He thought of it as an instrument for gaining maritime and military supremacy and for demonstrating the principles of optics. It took six months before he considered using it to study the heavens. Why? This was the forbidden zone that was the province of the church. (An accounting of this is well told in Daniel Boorstin's *The Discoverers*.)

In our competitive world, the shelf life for technology is decreasing, while the competition is increasing. Centers for the Performing Sciences need creative individuals who seek not only to create technology but also who have enough entrepreneurial spirit to put it to work for society.

Chapter 10
The Show Must Go On

A Center for the Performing Sciences is the stage where science emerges from the laboratory to perform for society—where an audience can gain access to and benefit from it. When that happens, society benefits in two ways: First, a new technology is spun out that improves the quality of life, creates new jobs, and stimulates the economy. Second, if the institution receives a fair equity and/or royalty position and follow-on R&D support, a mechanism is created that provides revenue for the institution's future growth.

Visitors often come to HARC hoping to receive a "plug and play formula" that they can take back to their own community. I caution them that there is a period of trial and error that they simply must experience. What works in one part of the world will need to be fine tuned to work for the culture, the economics, the talent pool, and the circumstances of another part of the world. Just as there is no formula available to establish a Center, there is no "set" dollar amount that I can share that will cover all the costs needed to create and operate such an institution.

My own experience in the start-up of HARC as well as with other private companies has been that most new ventures are undercapitalized and end up nearly starving to death because they had inadequate funding as opposed to inadequate technology.

One can have top management and the best technology, but, if the institution has insufficient financial underpinning, nothing is going to happen, at least not for very long. It takes fuel to fire the engine. When it comes to initial funding, a guiding principle must be to take the long view. The histories of most all private research institutes are replete with examples of financial struggles in the early years.

A particularly interesting example is noted in Weldon B. Gibson's *SRI: The Founding Years*. Gibson credits banker and SRI Trustee Charles B. Blyth with getting SRI through at least three financial crises in its earliest years. At one point, in late 1948, the author reports that Blyth almost single-handedly saved the institution from being "liquidated for financial reasons" when he arranged for the institution's refinancing. Often Blyth had to stand up to lending institutions and even other trustees who doubted the institution's ability to support itself in the long-term. But he never wavered in his conviction of the institution's promise.

Gibson, a founding member of SRI's research staff, writes that "whatever success SRI may have had in later years—and it has been considerable—is in many respects a testimonial to Blyth's firm support when it was so greatly needed in the late 1940s and 1950s."

Even the perception of being financially stable, particularly in a young institution, is very important. For instance, if people believe that the Center will be subject to a period of large cash demands and assume that the institution is stressed, it can damage morale as well as the institution's ability to attract and retain top talent. Long-term commitment, tied to realistic expectations of performance, is essential to institutional stability.

The greatest challenge in raising philanthropic dollars is establishing a new constituency. It is not built in. After all, this center does not have alumni who earned degrees there, or parishioners who achieved spiritual renewal, or a base of patients it has cured. The center has talent and economic potential for the community. That's where it begins.

At first, it will seem virtually impossible to compete for community support. With time, however, the support will build with those companies that have become healthier and wealthier as a result of the technologies and services the center has provided. Their loyalty can be demonstrated by continued contract research and technology development partnerships as well as by philanthropic support.

Other philanthropic prospects are those rare individuals and foundations who truly understand the present and potential value to the community's future prosperity. For HARC, oilman and real estate developer George P. Mitchell's continued support has amounted to more than $40 million in operating funds from personal and corporate donations, a 100-acre campus, and a pledge to match other endowment gifts (up to $50 million) in the years to come. George's efforts to introduce leaders of business and government to HARC and to win their support have been equally helpful.

The reason for all this generosity? George responds simply, "HARC has the potential to accomplish much for the benefit of many." HARC is his legacy.

Credibility and reputation are at the heart of successful contracts and grants for research consortia. The mechanism by which contracts and grants are won at a Center for the Performing Sciences is not much different from the way it is done in a university or industry setting. Key people, with an established reputation, submit clear, well-written proposals that communicate the institution's commitment and ability to do the work. Responding to solicited requests for proposals is always an important avenue. There is also potential for sending out unsolicited, but tightly targeted, proposals. So, build relationships with funding agencies and send solid proposals with creative arguments about society's needs and involve university, industry, and government talent and institutions.

One may ask, "But, how does a young institution gain an established reputation?" It takes time and performance. However, one of the benefits of a collaborative institution is that it draws from the credibility of its participants. Hence, a relatively young institution such as HARC benefits greatly from its affiliation with well-established collaborative institutions such as our founding universities: Rice University, Texas A&M, the University of Houston, and The University of Texas at Austin. Many of HARC's center directors hold joint appointments at these institutions.

In order for the collaborative relationship to be encouraged, the partner must receive value. In HARC's case, this has meant bringing talent together on projects that no one single institution alone could attempt or conducting classified or proprietary research for industry. Partnering with established agencies, companies, and universities builds reputation.

An article in *The Economist* (June 8, 1996) describes an innovative way in which the Center of Advanced European Studies and Research is to be funded. Slated to open in 1999 in Bonn, Germany, CAESAR will receive a one-time infusion of roughly a half a billion dollars through federal and state money. A private foundation created by the legislature will operate off of the interest from the initial investment. Its goal will be to recruit bright young scientists and engineers who will create new technologies useful to the community, and in time, who will bring additional income to the institution. This funding mechanism frees the institution—and its scientists—from the yearly jockeying for continued government support. I find this an enlightened strategy and approach.

Another creative funding arrangement is found at the Netherlands Study Centre for Technology Trends (STT), a nonprofit partnership with public funding from four government departments and equal private funding from the Royal Institution of Engineers in the Netherlands plus over 50 Dutch and Flemish companies and research establishments.

At STT, the majority of the public funding and all private funding is provided on an annual basis as opposed to a project basis. The Board of the Centre, therefore, is largely independent in its choice of projects. According to Erik van de Linde, STT director, "On one hand, with a staff of nine, STT would both lose too large a chunk of valuable time if forced to acquire funding on a project basis as well as lose its academic freedom to study trends that stretch farther than market mechanisms (i.e., farther than 10-15 years). On the other hand, the annual character of the funding guarantees that the Centre's constituency is continually updated." STT's funding mechanism has been in place since the foundation of the Centre in 1968 and even allows for modest growth of its activities into the next century.

Today's politicians seem to be won over easily by programs that generate jobs, particularly higher paying jobs for more skilled laborers. It is important to make sure that legislators and their constituencies understand the Center's economic scope, especially when a resulting product will not be manufactured locally. They must understand the benefits of wealth and revenue generation as well as jobs. Value still accrues when the Center creates and licenses technology that flourishes in the global village. It will still return the investment to the community not only by enhancing the Center's reputation but through royalty payments which help fund the next project.

We need to broaden our thinking. There is value to be gained for all the players when we seek win-win opportunities that can contribute to the growth of the community through the creation of knowledge-based products and technologies.

As the organization begins to mature and gains experience, there will be ample opportunity to negotiate royalties, equity positions and other income streams during the technology transfer process. Those companies that have benefited from a technology's development will most likely want to continue the partnership with a Center through additional contract research. Successful technology transfers also result in enhanced reputation and credibility which provides greater opportunity to form new alliances with industries that want to enjoy similar benefits.

A sound approach to funding is for both the public sector and private sector to join forces—creating public-private partnerships—to secure the finances necessary to create and sustain Centers for the Performing Sciences. It also makes sense to network these Centers together globally. Just as communities in today's global village cannot live in isolation, Centers need to be linked and to work together for a number of reasons, the most obvious being the need for talent and technology.

Imagine what could be accomplished if Centers collaborated with partners around the globe. Researchers with a problem to solve in North America, Asia, or Europe would have the benefit of their colleagues' ideas at similar Centers throughout the world. Properly coordinated, an intellectual-product trading company can emerge. I think of these as the knowledge brokers. The solution to the problem is independent of who or where and extraordinary efficiency is possible through cooperation.

HARC's Intellectual Property Policy, included in the Appendix, provides specific ideas on how to receive value from our work. With enough good fortune and patience, a long-term goal of becoming self-supporting is possible.

Chapter 11
Value Added

One of the great pitfalls of today's Wall Street mentality is that investors expect quick-term (at a quarterly report rate) results. Rarely in history has a challenging but exciting new opportunity arisen that has been as easy or as swift to achieve as originally perceived.

Two hundred years ago, the United States faced a challenging economic need. President Thomas Jefferson put together a team of about 40 men to find a direct water route from St. Louis to the Pacific coast. He anticipated that the mission could be completed in one to two years and at moderate cost and that great trade would result. That campaign, better known as the Lewis & Clark Expedition, encountered many obstacles along the way.

I thoroughly enjoyed reading an accounting of that journey in Stephen Ambrose's *Undaunted Courage*. First and foremost, there was no water route. But there were snakes, bears, hostile Indians, biting cold, a number of accidents, the treacherous Rocky Mountains, and severe food shortages. While the long-sought Northwest Passage was never found and the expedition took a great deal longer and cost a great deal more than expected, no one could discount the net value of exploring and mapping the West and opening the way to get value from the Louisiana Purchase, the 828,000 square miles of land west of the Mississippi that the United States bought from France in 1803.

As our communities learn more about the new intellectual frontier, they will better understand about investing in an expedition to tap its potential rewards. In some ways the adventure will be just as challenging as that of 1804. There will be threatening barriers like the Rocky Mountains that simply have to be crossed. The mission will be to form the team that can find the best path to take an idea, generate from it a new technology, nurture it into a product, and get that product out in the marketplace where it will compete effectively across the entire globe.

Of course, there is much likelihood for adversity along the way. It is going to take committed people with passion, tenacity, and resources. Expectations should be to push this frontier, learn the culture and the cultural differences, and conquer the obstacles.

I cannot restate too often the importance of taking the long-term view. It is simply not realistic to expect an activity like this to come into being and start paying dividends in a short time. Instead, we must set reasonable expectations and define measurable goals when we launch a Center for the Performing Sciences.

As a general rule, I recommend that the community initially be prepared to invest over a ten-year period in order to provide the basic infrastructure needed or put together a creative endowment as in the CAESAR example mentioned earlier. A long-term goal should be to create an institution that will become self-sustaining with a resource base to get it through the tough periods ahead.

In a knowledge-based society, we must recognize that the wealth of the community depends upon its ability not just to create knowledge, but more importantly, to get value from it. Therefore, performance goals for the Center should include working with other critical sectors of the community (government, industry, and academia) in ways that promote the transfer of intellectual properties to industry so that new products, jobs and wealth will bring about a higher quality of life.

The difference between merely creating jobs in contrast to creating real wealth comes from knowledge—and knowledge comes from education. Another goal must be to educate our community's citizens so they understand and appreciate the process of creating intellectual property and obtaining the benefits.

As the Center matures and becomes more successful in transferring technologies and products to the marketplace, more and more people will become involved. Our continuing role will be to help them understand how to play the game better. That, of course, is really what it's all about—sharing the knowledge and establishing the mechanism where the technology transfer learning process is much more efficient than it historically has been.

Each experience in transferring a technology to an existing company or in creating a new company as a result of a new technology becomes, in a sense, a case study. Case studies provide great insight on how to streamline the technology transfer process. They also provide a ready list of measurable accomplishments: number of patents, technology licensing agreements, companies strengthened, new companies created, jobs created. The process will also point out areas needing improvement, such as capital availability, intellectual property law, incubators, and mentors.

It is not enough to amass the talent, build the research facilities, and develop the programs. To win broad-based support, one must constantly promote the importance of the institution and engage the community. Whether it is a grants maker, a politician, a community leader, or a corporate manager, the public must well understand the role that this new institution—designed to shape and drive the future—will play in a knowledge-based economy. It does not happen overnight.

On the other hand, as companies in one's own community and beyond are forced to deal with rapidly changing technologies, erratic marketplaces, and demanding stockholders and directors, all can begin to appreciate an organization that has as its primary mission keeping pace with changing technology.

Finally, remember to reach out to as broad a cross-section of the community as possible and to communicate the value of the institution even after it has the resources in hand. There will be a continuing need to do this.

Chapter 12
Rules of Engagement

When members of communities in North America, Europe, and Asia, as well as from other regions of the globe, have visited HARC, they have come seeking answers on how to attain a higher quality of life for their community. While they share a common curiosity and desire to tap into their community's resources, they also face the same odds of getting there. The wealth of any community is no longer tied to natural resources or the industrial base but to how well its leadership is able to leverage knowledge.

I have tried to share with our visitors some of the concepts, philosophies, and ideas (both original and borrowed) employed when establishing HARC. Other institutions have used different approaches that have worked as well. Themes common to HARC and others are:

- Private is better than public.
- Public/private partnerships are the most viable. The private sector is much better at speaking the language of competition, product development, and marketing while public institutions have far greater political acumen. Indeed, in the CAESAR example from Chapter 10, we find a clever way to make use of public funds for creating a private foundation. The benefit is to provide CAESAR with permanent income stream and to insulate it from changing political whims.
- It must connect to society's needs.
- It must respond to a changing marketplace.
- It must form collaborative ties with university, industry, and government. The reality is that each of these sectors must become more attuned to the commercial value of knowledge—and the value education has in nurturing that knowledge.

Chapter 13
The New World Order

Many are asking whether their community is ready to play this game, and if so, can they find the support required to have a real chance at success.

My response is simple. Just as in the case of MCC in Texas, “This is not something that would be nice to do, but something that must be done.”

We must remember that the difference between creating jobs and creating wealth is knowledge. We must understand that knowledge is the new coin of the realm and that in order to gain a competitive advantage in a changing global economy, we must take advantage of our community’s intellectual resources—its human capital.

As we begin the process of creating Centers that specialize in technology transfer, we must rededicate ourselves to the loftier goals of education itself. We must look at education as a lifelong process integral to a community’s ability to improve the quality of life. Success will depend on our capacity to think creatively and to solve technology-based problems to help our already stressed planet accommodate a population that is expected to double in size in the next 50 years.

Imagine the technological challenges we will encounter as the population shifts from today’s 4.8 billion people to the anticipated 11 billion in the year 2050. What will it take to feed, house, and employ these people? How can we reduce the income disparities between rich and poor nations? How can we achieve sustained growth that will not further deplete our natural resources or threaten our environment? I firmly believe the solutions to the problems we will encounter in the 21st century will be based in science and technology, in education, in cultural understanding, and in reaching out to people with whom we historically have not felt the need to interact. The solutions will also require collaboration and communication.

We must look at change as our friend. We must celebrate the opportunity to be pioneers once again—as we cross the knowledge frontier. It is a frontier that is fraught with risk and hidden danger. Yet, it is one filled with promise. Our willingness to embark upon this frontier—to take risks, to meet unknown and unforeseen challenges, and to fully invest in our intellectual resources—will determine how well we meet and help shape the future. Communities that embrace and support the knowledge seekers and the knowledge brokers are the ones that will succeed in a knowledge-based economy.

A final measure of success could be when the average citizen knows how to cross the forbidden zone and get value from an idea as easily as he or she knows how to catch an airplane from St. Louis to Portland.

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Appendix

Houston Advanced Research Center Brief History
Houston Advanced Research Center Accomplishments
Houston Advanced Research Center Intellectual Property Policy

Houston Advanced Research Center Brief History

Through the events, large and small, that have shaped our world, certain defining moments have emerged. From the agricultural era to the industrial age, we can now comprehend those sweeping changes that must have seemed perplexing to those who lived through them.

The Houston Advanced Research Center was conceived in just such a time—as society struggled through a transition from the industrial to the information age.

HARC's primary mission—science performing for society—is of critical importance in today's world. With a short history, HARC is still in its own defining era. But these first years have given form to an institution of great promise.

HARC owes its origins to the fertile imagination and initiative of Houston oilman and developer George P. Mitchell. In 1974, Mr. Mitchell and his wife Cynthia assembled a group of business and academic leaders who shared a common concern about global issues. Together, they forged plans for a multi-year program to seek solutions. The result was The Woodlands Conference Series, which began in 1975.

Mitchell and others became fascinated by the synergism, the working together of private businesses, government representatives, and academicians in these conferences to produce together something seemingly greater than the parts. He looked at what was being done by North Carolina's Research Triangle, a planned research park created in 1959 by leaders from business, academia and industry to attract companies doing world-class research and development. Companies located in the Triangle had access to the resources of three universities nearby—Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill. The Park's greatest asset was Research Triangle Institute, where collaborative research was carried out by talented scientists and engineers from institutions throughout the state.

Mr. Mitchell also drew upon the success of new technology-intensive developments, such as Silicon Valley near Stanford and Route 128 near MIT. He believed that The Woodlands, Texas—the home of his planned community just north of Houston—was an ideal site for a research forest and a university consortium.

"I believed a lot could happen if we could get Texas A&M, Rice, the University of Houston, and The University of Texas to work together on projects they couldn't do individually," he recalls.

Mitchell soon began discussions with Texas A&M University, Rice University, and the University of Houston to establish the Houston Area Research Planning Committee. The group awarded a contract to Arthur D. Little, Inc. for a feasibility study in early 1980. The firm's report concluded that The Woodlands was a viable location to establish a center in basic, applied, and policy research funded by contracts, grants, and gifts.

1982

- On September 7, a partially assembled board of directors of the Houston Area Research Center meets to develop a mission statement and an organizational charter.

1983

- The Woodlands Conferences and associated Mitchell international essay competitions lay the groundwork for HARC's Center for Global Studies—a policy division that today focuses on global environmental issues, sustainable development, and the social and policy implications of science and technology.
- HARC's first research program, a laser study of materials sponsored by the Strategic Defense Initiative (SDI) program, is established.
- The Department of Energy (DOE) invites design proposals for the construction of a multi-billion dollar atom smasher, later known as the Superconducting Super Collider or SSC, requiring that funds be awarded to a "single" institution.

1984

- The University of Texas at Austin joins the HARC consortium.
- The Texas Accelerator Center (TAC) is established at HARC and receives $1.6 million from the DOE in support of its SSC program.
- Following a nationwide search, W. Arthur Porter, whose work at Texas Instruments had led to the first patent on an automated manufacturing system for integrated circuits, is elected president of HARC.
- HARC's Center for Growth Studies begins publication of *The Woodlands Forum*, featuring interviews with such notables as Ted Turner and former President Jimmy Carter.
- TAC completes development of a superferric (iron-shielding) accelerator magnet, an outgrowth of design work for the SSC.

1985

- Created by an act of the Texas Legislature, the Geotechnology Research Institute at HARC opens to improve technology used in oil and gas exploration.
- Negotiations are completed for a $10.4 million bond agreement to finance development of the HARC campus.
- HARC delivers a five-volume analysis of six potential Texas super collider sites to then-Governor Mark White.

1986

- Six HARC centers are operational: geotechnology, materials sciences, laser applications, space applications, accelerator, and global studies.
- NEC locates its first supercomputer in North America—the NEC SX-2—at HARC.
- HARC and its member universities gather at the site of a planned 50,000 square-foot office and research facility for ground-breaking ceremonies.

1987

- HARC moves from rented space to its new 100 acre campus.
- The Collaborative Institutions Program is created to encourage other institutions to form alliances with HARC.

1988

- TAC teams with Baylor College of Medicine to pioneer the use of its superferric magnet technology in magnetic resonance imaging.
- John Butler, Jr., chairman and CEO of GeoQuest International Holdings, Inc., is unanimously elected as chairman of the HARC board.
- An Astroparticle Physics Group is established.

1989

- A $1 million award from Advantest Corporation endows HARC's Advantest Research Chair and Scholarship Program.
- A three-year, $1.5 million grant from the Houston Endowment supports the Geotechnology Research Institute (GTRI).
- GTRI opens s Seismic Processing Center to advance processing methods for the energy industry.
- The Texas Accelerator Center and the Laser Applications Research Center move into HARC's second building, a 61,300 square-foot research facility.

1990

- HARC's name changes to the Houston Advanced Research Center.
- The Texas Accelerator Center completes construction of the SSC's "first foot"—the instrument designed to discharge negative ions and send them speeding on their path into the main accelerator ring.

1991

- HARC joins with partners in the U.K., Switzerland, and Spain to form RSE Remote Sensing Europeo, SA., a remote airborne sensing and environmental monitoring company.
- Construction of HARC's microwave imaging facility is completed.
- The Energy Research Clearing House, a cooperative venture of 29 energy companies, is established. Housed at HARC, the independent, industry-driven organization solicits and sponsors research projects of mutual interest.
- The Center for Global Studies holds an international conference on regional responses to global warming, drawing participants from 10 countries and publishes a text on U.S.-Mexico industrial integration.
- HARC opens new laboratories for DNA technology and geographical information systems.
- HARC hosts the first International School of Astroparticle Physics.
- HARC's first spin-off, Emmetropix, is created to commercialize photo-thermal corneal shaping technology.

1992

- Two international meetings are organized under HARC's leadership: the International Geoscience and Remote Sensing Symposium as part of IGARSS'92 and the second international school for astroparticle physics, focusing on "Black Holes, Membranes, Wormholes, and Superstrings."
- Emmotropix is acquired by Sunrise Technologies, Inc. of California, a developer and manufacturer of solid state medical laser systems.
- The DNA Technology Laboratory, with colleagues at Baylor College of Medicine and MIT Lincoln Laboratory, receives a three-year, $2 million NIH Human Genome Program Development grant.

1993

- Two members of the Geotechnology Research Institute publish a book for the Gas Research Institute on the using AVO analysis to increase the success rate of drilling.
- HARC, MIT, Baylor College of Medicine, and several private biotech firms win a $9 million matching grant from the Department of Commerce's

Advanced Technology Program to develop microchips for speeding DNA sequence analysis. HARC, the U.S. Department of Energy, and The Wellcome Trust, host the Second International Sequencing by Hybridization Workshop.

- HARC researchers set a world record for the highest current through a superconducting cable.
- HARC's Technology Officer Jack Kilby receives the coveted Kyoto Prize for his invention of the microchip some 30 years earlier at Texas Instruments.
- The 100-acre HARC campus is named in honor of its founder George P. Mitchell.

1994

- Genometrix, a spin-off company, evolves from DNA-based research started at HARC.
- Unocal Corp. donates its rock physics laboratory to HARC.
- HARC wins a three-year grant from the State of Texas to develop and test superconducting magnetic energy storage systems.
- HARC initiates the Environmental Foresight Program to determine the most pressing environmental risks in an eight-county region in and surrounding Houston.
- HARC and the National Academy of Sciences launch the Global Commons Project, a multi-year, multi-million dollar effort to promote sustainable development around the globe.
- HARC Technologies Inc. is created as a for-profit subsidiary to commercialize HARC technologies.

1995

- Texaco, Inc. transfers its geochemistry research laboratory to HARC.
- HARC acquires an NEC SX-4 Series supercomputer to assist with three- and four-dimensional seismic processing.
- HARC, working in partnership with Varian Instruments, delivers the world's first actively shielded magnet for NMR spectroscopy to the University of Texas Medical Branch at Galveston.
- HARC and Baylor researchers win a $2.1 million grant from the National Institute of Allergy and Infectious Diseases to develop ultra-fast diagnostic tools to detect certain strains of tuberculosis.
- HARC's Center for Global Studies coordinates the first Dia del Rio—Day of the River—Celebration, an event to draw bi-national attention to the environmental problems affecting the river basin. The resulting Rio

Grande/Rio Bravo Coalition now works with local communities to encourage sustainable practices in the region.

- HARC celebrates the fifth year of the Junior Laureate Program, a summer internship program supported by the Houston Livestock Show & Rodeo, for students enrolled in the Texas Academy of Math and Science.

1996

- Shell E&P Technology Company adapts HARC-C™ compression technology for use in its internal seismic applications and announces plans to license and market the technology for the energy industry.
- Houston Environmental Foresight publishes the results of a two-year study identifying and ranking the Houston region's most pressing environmental risks.
- The Geochemistry Laboratory, funded by a multi-million dollar grant from Texaco, opens.
- The Fondren Foundation underwrites a Telemedicine Laboratory. A first symposium on the economics and politics of emerging telemedicine technologies is held that fall.
- HARC teams with MCC (Microelectronics and Computer Technology Corporation) and IC² Institute, both of Austin, to host the Texas Technology Summit. As a result, Governor George W. Bush announces the formation of the Texas Science and Technology Council.
- The EPA awards HARC $700,000 to develop workable solutions for water management in the Rio Grande Basin.

1997

- HARC transfers HARC-C™ compression technology to Compression Engines, L.L.C.
- HARC addresses impact of Telemedicine Legislation in second annual telemedicine symposium.
- Houston Endowment awards HARC $300,000 to begin second phase of Foresight Program.
- HARC opens incubator program to assist technology-based startup companies.
- HARC and UH's Energy Institute publish *Guide to Electric Power in Texas*.
- The De Lange-Woodlands Conference is organized by HARC's Center for Global Studies and Rice University's Energy and Environmental Systems Institute to explore the transition to sustainable development globally. At the three-day international colloquium, Dr. Marcelo C. de Andrade of

Brazil is named recipient of the 1997 George and Cynthia Mitchell International Prize for Sustainable Development for his efforts to conserve tropical ecosystems.

Houston Advanced Research Center
Major Accomplishments

HARC's accomplishments fall in a range of categories: forefront scientific, economic, community, and education.

Scientific Accomplishments

- HARC's work in magnet design and site feasibility was instrumental in bringing the SSC project to Texas. HARC later built the SSC's ion source and low energy beam transport.
- HARC researchers have made advances in the field of superconducting magnetic energy storage (SMES) and led a consortium of key industry players interested in superconducting power system technology development. Feasibility studies of sites in Texas are underway.
- HARC advances in the field of self-shielded magnet designs for MRI systems and NMR spectroscopy led to the development, assembly, and delivery of the world's first actively shielded magnet for high resolution NMR spectroscopy at a proton frequency of 400 megahertz.
- Enhanced technologies to improve oil and gas exploration, including imaging of sub-salt structures and hydrocarbon indicators, are part of HARC's Geotechnology Research Institute (GTRI) service to the energy industry. GTRI develops imaging tools to locate hard-to-locate reserves for companies such as Anadarko, one of the first to find oil below the salt. GTRI has received more funding in exploration related research than any other educational or nonprofit institution in Texas.
- In 1995, HARC laser physicists were first to observe "Lasing Without Inversion," an effect with possible applications ranging from new types of lasers to optical microscopes with x-ray resolution. They extended this breakthrough in 1996 to achieve an operating laser based on the concept.
- HARC advances in materials science include patents for processes creating thin-film diamond and for remote temperature measurements.
- HARC developed and patented a spline-based wavelet image compression technology, HARC-C™.
- HARC unveiled new mathematical models linking gravity and quantum mechanics in 1993, and later, the discovery of a surprising connection

between string theory and quantum Hall conductors. (Effects measured in the conductors are being used to prove aspects of string theory.)

- HARC, NASA, FEMA, and industry sponsors have successfully flown a number of missions to test ALTMS, an airborne laser topographic mapping system sensor developed by HARC and NASA.
- HARC manages the Genosensor Consortium, an $18 million, private-public partnership which includes MIT, Baylor College of Medicine, and Beckman Instruments, begun in 1992 to advance the development and manufacture of DNA chips to diagnose genetic disease. Genometrix, Inc., which opened in The Woodlands in 1994, is a spinoff of this research.
- HARC researchers set a world record in the winter of 1993 for highest current through a superconducting cable, a test that could have far-reaching implications on the cost and availability of electricity.

Education

- HARC has organized or sponsored numerous conferences on topics related to sustainable development, technology transfer, international business, astroparticle physics, quantum optics, remote sensing technologies, and telemedicine.
- HARC acquired the first supercomputer for academic use in Texas. Today HARC's Geotechnology Research Institute uses its supercomputer for imaging complex buried structures in the search for oil and gas and makes this facility available to the energy industry.
- Through summer internships sponsored by the Livestock Show & Rodeo, HARC has provided hands-on experiences in math and science to gifted young Texans since 1991.
- From its original four founding member institutions, HARC has grown to a network of 10 collaborative institutions. They are the University of Houston, Texas A&M University, The University of Texas at Austin, and Rice University, as well as Baylor College of Medicine, Duke University, Louisiana State University, Sam Houston State University, the University of Texas Medical Branch at Galveston (UTMB), and ITESM (the Monterrey Institute of Technology and Higher Education, Mexico). These universities encourage their faculty and staff to participate in joint research programs.

Community

- HARC's Center for Global Studies has led public-private efforts to solve economic and natural resource management problems in the Rio Grande Basin, northeast Brazil, and the Greater Houston area. In 1996, CGS published "Seeking Environmental Improvement," which identified and ranked Houston's most pressing environmental risks. The work on the border resulted in the formation of the Rio Grande/Rio Bravo Coalition in El Paso.

- HARC and the National Academy of Sciences are partners in the Global Commons Project, a first-ever effort to develop a template for captains of business and industry to move the world towards sustainable development.

Economic Impact

- In 1995 Texaco, faced with downsizing its R&D, entered into a unique alliance with HARC to relocate its geochemistry laboratory to the HARC campus. The alliance helped preserve Texaco's geochemistry research efforts, intellectual property, and jobs through the creation of a new 6,000 square foot facility at HARC. The lab provides a neutral environment for Texaco and other companies to share in the research products of a world-class geochemistry facility. A similar agreement with UNOCAL resulted in moving its cutting-edge Rocks Physics Laboratory to HARC.
- HARC helped to establish and hosts the Energy Research Clearing House, an industry-led consortium that provides the means for member companies to leverage its research dollars.
- To market its compression technology, HARC created Compression Engines, L.L.C., which now operates in Houston. Shell E&P Technology Company has already licensed the technology and is marketing it for use in seismic work.
- HARC has become a focal point for international interest in technology-based opportunities. Two examples:
  - NEC's locating its supercomputer division at HARC for a decade. (NEC recently moved its offices to have a major presence in The Woodlands).
  - Scottish Enterprise's interest in creating its own HARC-like entity.
- HARC provides an incubator program for emerging technology companies. It has also fostered ASSET, an organization created to provide support for the scientific and technical community in The Woodlands.
- HARC's development of technology for laser photothermal corneal shaping to correct refractive eye disorders resulted in the creation of Emmetropix Corporation, a company later acquired by Sunrise Technologies, Inc. of California.
- HARC generates $37.7 million annually in total expenditures within the Greater Houston economy, according to a 1996 report by economist Dr. Ray Perryman.

- Intellectual Property history as of press date:
  - 41 U.S. patent applications filed
  - 27 patents issued
  - 20 patents or patent applications transferred to others
  - 8 entities created
  - 2 active licenses
  - 150+ companies strengthened through R&D contracts
- In 1997 royalties and income from HARC's intellectual property activity fully funded the operation of its Intellectual Property Office.
- HARC continues to exist in Texas as a nonprofit, university-linked research institution with a mission of coalescing public-private teams to leverage research for the benefit of society.

Houston Advanced Research Center Intellectual Property Policy

1. Purpose

To promote the progress of science and the useful arts by stimulating the development of ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations by HARC personnel; to utilize the benefits of the patent, copyright, and all other intellectual property rights systems; and to encourage other research institutions to collaborate with HARC on development of ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations.

2. Scope

This Policy and attendant Procedures apply to HARC's faculty, staff, students, consultants and any others ("Participants") who conceive, make, develop, reduce to practice, invent, create or acquire ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations, whether he or she does so individually, jointly or otherwise in conjunction with others, whether during business hours or otherwise, and whether on HARC's premises or otherwise, while participating in a HARC program, or utilizing HARC funds, space or facilities, or as a result of or in connection with the administration, research, or other activity conducted by HARC or supported directly or indirectly by HARC resources or funds administered by HARC, regardless of the source of such funds.

For the purposes of this Policy and the attendant Procedures, the terminology "ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations" includes and embraces all intellectual property and intellectual property rights of every type or character whatsoever, including but not limited to, concepts, improvements (whether or not patentable), technical information, trade secrets, developments, know-how, methods, techniques, formulae, processes, computer programs, all expressions that are the subject matter of copyright, trade names and marks, manuals, manuscripts, and proposals. All such ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations are sometimes referred to herein as the "Technology."

For the purposes of this Policy, the terminology "conceive, make, develop, reduce to practice, invent, create or acquire" includes and embraces any and all activities comprising any aspect of the process of effecting, generating, perfecting, maintaining, protecting, disposing of and/or commercializing any and all aspects of the Technology.

3. Policy

Unless otherwise provided by action of the Board of Directors, any and all Technology within the Scope of this Policy are and shall be the property of HARC. HARC shall be the owner of all of the Participant's worldwide right, title and interest in such Technology, including all royalties and revenues derived therefrom. HARC shall be the owner of not only the physical things in which the Technology is embodied but also of all of the intellectual property rights therein provided by any and all jurisdictions throughout the world, including the right of first publication, all rights of copyright, and all rights to file for, obtain and maintain patent and other industrial rights. Each Participant hereby assigns and agrees to assign his or her worldwide right, title and interest in the Technology to HARC in accordance with this Policy and to assist HARC and its nominee, at any time, in the protection of HARC's worldwide right, title, and interest in and to the Technology, including without limitation, the execution of all formal assignment documents requested by HARC or its nominee and the execution of all lawful oaths and applications for applications for patents and registration of copyright in the United States and foreign countries. To the extent this ownership Policy is inconsistent with the terms of any applicable agreement with a third-party sponsor or provider of funds, HARC's agreement with such sponsor shall control.

4. Categories of Technology

For the purposes of this Policy, ideas, discoveries, inventions, works of authorship and other intellectual creations are separated into the following three (3) categories:

(a) Technology which is subject to the terms of government sponsored research or sponsored research between HARC and outside entities.

Government Sponsored Research
With few exceptions, grants and contracts for research sponsored by the federal government reference Section 6 of Public Law 96-517, which provides that HARC acquires rights to inventions conceived or

first actually reduced to practice in the performance of the research. In most cases, the government will reserve an irrevocable, non-exclusive, royalty-free license to practice or have practiced for or on behalf of the United States throughout the world the Technology conceived or first actually reduced to practice. However, the rights of a government in Technology resulting from government sponsored research may vary depending upon the law, rules, regulations, and policies of the government in effect at the time. These provisions usually are set forth in the individual award documents.

Other Sponsored Research
It is desirable that contracts with industrial sponsors provide for HARC to acquire full rights in the Technology in exchange for a license to the sponsor. It is desirable that grants from industrial sponsors, as well as grants from private foundations, not have patent or other intellectual property right restrictions. Normally, however, the grantors will be entitled to a right of first refusal for a license under any Technology that HARC may acquire as the result of work supported by the grant.

Jointly Sponsored Programs
A Collaborative Institution is a public or private institution which formally affiliates and/or participates in shared research at, or for, HARC. Collaborative Institutions may hold some rights to Technology resulting from programs in which the Collaborative Institution has participated or which involve the use of research equipment or other laboratory facilities, materials or services which are maintained by or derive support from the Collaborative Institution.

(b) Technology developed without any HARC support.

Unless otherwise provided in an agreement between or among the individual(s) inventors, authors, creators, or developers, HARC, a Collaborative Institution, a third-party sponsor, or provider of funds, ideas, discoveries, inventions, information, data, works of authorship and other intellectual creations resulting from activities which are not involved in a HARC program and have received no support (direct or indirect) from HARC as described in the Scope of this Policy, shall be the property of the inventor, author, creator or developer, free of any limitation which might otherwise arise by virtue of HARC employment.

Technology developed by individuals affiliated with HARC while involved in programs funded and conducted at the Collaborative

Institutions in which the individual is not participating in a HARC program or utilizing HARC funds, space or facilities will be governed by the intellectual property policies of that Collaborative Institution.

Technology developed or acquired independently of HARC support or use of HARC space, equipment or facilities by affiliated individuals who are not Participants, shall, if requested by such affiliated individuals and if such Technology is consistent with HARC's mission, be considered for further development or commercialization by the Intellectual Property Review Committee. The ultimate ownership of this Technology and the rights of the parties therein shall be as agreed upon in writing, and in advance of any further development or commercialization, by the such affiliated individuals and the Vice President for Business Affairs with the approval of the Intellectual Property Review Committee.

(c) Shared Technology.

Because the terms and conditions of each research program are unique, a blanket policy which addresses the disposition of Technology in all instances would be difficult to achieve. In the event Technology is jointly conceived, made, developed, reduced to practice, invented, created or acquired between HARC and another institution or individual, the sharing of such shall be handled on a case-by-case basis. In those instances where Technology is jointly conceived, made, developed, reduced to practice, invented, created or acquired, HARC reserves the right to take the lead in licensing or otherwise commercializing the Technology in appropriate cases, while providing an equitable return of royalty income to the co-inventors, co-creators, co-developers or co-acquirers.

5. Protection of HARC's Technology

Participants shall not at any time make any unauthorized use or disclosure of any of the Technology. Upon termination of Participant's involvement in a program or upon request by HARC for any reason, Participant shall promptly deliver all documents, materials, and physical things (e.g., computer data) containing or embodying any aspects of the Technology, and all copies thereof, to HARC.

Participants will cooperate fully with HARC in the process of developing, effecting, generating, perfecting, maintaining, protecting, licensing or otherwise commercializing the Technology.

Any Participant or staff member engaged in consulting work or in an outside business is responsible for ensuring that his/her external agreements are not in conflict with the intellectual property policies of HARC. The Intellectual Property Office will, upon request, provide assistance in determining his/her external agreements are not in conflict with the intellectual property policies of HARC. HARC's rights and the individual's obligations to HARC are in no way abrogated or limited by the terms of such agreements. Staff members shall make their obligations to HARC clear to those with whom they make such agreements and should ensure that other parties to the agreement are provided with a current statement of HARC's intellectual property policy.

No agreements affecting HARC Technology shall be entered into without the approval of the Vice President for Business Affairs (VPBA).

6. Distribution of Royalty and Licensing Income

(a) Royalty and other income resulting from the licensing or other commercialization of the Technology will be distributed annually, as follows:

(i) First, fifteen percent (15%) of such annual income shall be retained by HARC to support the general operating costs of the institution. The manner in which this fifteen percent is distributed within HARC shall be with the approval of the President.

(ii) The remaining annual income shall be retained by HARC until all costs directly attributable to the set of ideas, discoveries, inventions, improvements, data, original works of authorship, or other intellectual creation being commercialized have been recovered (this includes, but is not limited to, patent filing fees, preparation of license agreements, litigation, interference, administrative, legal, and marketing costs). In addition, HARC may in its discretion retain the reasonable, affiliated project development costs that were paid for utilizing HARC's discretionary funds (as distinguished from restricted funds received by HARC from a sponsor).

(iii) After HARC recovers the fifteen percent specified in subparagraph (i) and all of the reimbursements specified in subparagraph (ii), remaining annual income will be distributed according to the following sliding scale based upon cumulative income to HARC (including equity consideration):

\$0 - \$4,000,000	50% to HARC and 50% to inventor(s)
\$4,000,001 - \$12,000,000	75% to HARC and 25% to inventor(s)

$12,000,001 and above	90% to HARC and 10% to inventor(s)

The sum specified in this subparagraph (iii) shall be distributed annually to the Participants as soon as practical after the close of the fiscal year during which the income was received.

Income payable to a Participant shall survive termination of affiliation with HARC and in the event of death of the Participant shall inure to his/her estate.

Income to HARC shall be used for research programs and activities that are in furtherance of its scientific research mission.

(b) Equity:

HARC may enter into license agreements with Participant owned companies. However, it is desirable that such licenses will be comparable to those negotiated with unrelated third-party licensees. The terms may include royalty payment, equity interest, or a combination thereof, as consideration to HARC for the license. The emphasis in structuring license agreements with new company formations will be on helping the company become viable.

In the event HARC acquires equity from the licensing or other commercialization of its intellectual property, HARC will hold all equity (including securities, stock options, warrants, partnership interests, real or personal property, or any other non-cash consideration, etc.) until HARC in its discretion determines that such equity can be legally transferred and a valuation can be assessed. HARC, in its discretion, shall determine whether to liquidate equity prior to distributing the same to Participants. If HARC liquidates the equity, the proceeds of the liquidation will be distributed to the Participants using the same formula as that used for royalty income. Variations to this Policy will require approval of the Board of Directors.

If HARC has made unusually large contribution or investments with respect to the Technology leading to equity, provisions may be made for HARC to retain extra equity, as compensation for the added value. The determination of extra HARC equity will be made on a case-by-case basis, and must be approved by the HARC Board of Directors. HARC and its Board of Directors are delegated the authority to make these decisions in a manner that is in the best interests of HARC, taking into consideration the interests of the Participants.

HARC does not act as a fiduciary for any person concerning equity or other consideration received under the terms of this Policy.

(c) Other Distributions:

When HARC files a patent application in the United States Patent and Trademark Office, the HARC inventor(s) will receive a one-time payment of Five Hundred ($500) Dollars (to be shared equally among all inventors if jointly invented) payable on the filing of the application (there shall not be additional payments for the filing of divisional, continuations, or continuations-in-part, or reissue applications or the like).

(d) Right to Withhold Payment and Right of Offset:

If a Participant fails or refuses to cooperate with HARC as required by this Policy or the attendant Procedures or violates the provisions of this Policy or the attendant Procedures, HARC shall have the right to withhold payments otherwise owed a Participant under this Policy until such time as the Participant is in compliance with this Policy and the attendant Procedures. Moreover, if Participant's actions or inactions in violation of this Policy and the attendant Procedures cause damage to HARC, HARC shall have the right to offset from the sums otherwise owed a Participant under this Policy an amount equal to HARC's damages sustained as a result of the Participant's actions and inactions.

7. Delegation of Authority to the Board of Directors

All decisions with respect to all aspects of the effecting, generating, perfecting, maintaining, protecting, disposition and/or commercialization of the ideas, discoveries, inventions, information, data, works of authorship and other intellectual creations, and any and all of the intellectual property rights therein, covered by this Policy are expressly delegated to the Board of Directors of HARC. In effecting its decisions, the Board of Directors will primarily strive to protect the interests of HARC. If a Participant disagrees with the decision reached by the Board of Directors, the dispute will be limited to whether the Board of Directors reached its decision in good faith.

8. Binding Effect of this Policy and the Effective Date of this Policy

The Policy set forth herein, and the attendant Procedures for the disposition of the ideas, discoveries, inventions, information, data, works of authorship and other intellectual creations covered by this Policy, constitute an agreement which is binding to HARC employees, staff, visiting students and others as a condition of their participating in HARC programs or their use of funds, space or facilities.

This Policy and the attendant Procedures shall govern any and all disclosures of ideas, discoveries, inventions, information, data, works of authorship or other intellectual creations made to HARC after August 31, 1995. The Board of Directors reserves the authority to modify the terms and conditions of this Policy and/or the attendant Procedures at any time and to determine the effective date of such future modifications.

A highly competitive global marketplace demands that innovation keep pace with an accelerating rate of change. The shelf life for products and ideas keeps shrinking, and today a technology may have as little as a few months to a few years before it becomes obsolete. The author contends that the time has come for a new type of institution—one that can produce research products *and* get them to market before the window of opportunity is closed.

Writing in a conversational style illustrated with numerous anecdotes, Dr. Porter shares personal experiences, concepts, and ideas that have helped shape the Houston Advanced Research Center, his work-in-progress model of a Center for the Performing Sciences.

Porter asserts that the cultural wall between traditional academic institutions and the product marketplace is often too high and too difficult. He compares that wall to the "forbidden zone" which an electron must pass before it can be put to work producing electricity. But he believes that great challenges can be surmounted by people who are committed, willing to take risks, and unafraid, citing examples ranging from Thomas Jefferson to Ross Perot.

The Knowledge Seekers offers practical guidance for business, political and community leaders who may want to create a center in their own community.

W. Arthur Porter, Ph.D., is President, CEO, and Advantest Chair at the Houston Advanced Research Center and serves as vice-chairman of Governor Bush's Texas Science and Technology Council. He is also an Adjunct Professor of Electrical Engineering at Rice University and serves on a number of corporate boards. A fellow of the Institute of Electrical and Electronics Engineers (IEEE), he received the IEEE Centennial Medal for Extraordinary Achievement in 1984 and the American Society for Engineering Management's Technology Leadership Award in 1996. He was elected a corresponding member of the Swiss Academy of Engineering Science in 1991. He resides in The Woodlands, Texas.

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